A metal burner membrane

Field of the invention.

The present invention relates to a gas burner comprising a metal burner membrane.

Background of the Invention.

Prior art gas burners with different shapes and different burner membranes have been described e.g. in WO 02/44618 A1 and WO 01/79756 A1.
The first drawback of these burners is that for a given dimension, they do not allow for a large range in output power: at low power, i.e. if the gasflow is low, there is a risk for flame extinguishment, and at high powers, i.e. if the gasflow is high, there is a risk that the flame blows off. This results in the need of a range of burners that differ only slightly in dimensions (e.g. in their height) adapted to specific power ratings: a second drawback.
A third drawback of these burners is that different parts have to be punched, formed and welded together which leads to expensive burners. The welding seams themselves are weak points in the burner, because they are most susceptible to failure in the heating and cooling cycles that occur during the use of a gas burner. Hence, the weldings reduce the lifetime of the product, which constitutes a fourth drawback.

Summary of the Invention.

It is a general object of the present invention to eliminate the drawbacks of the prior art burners. It is a first object of the present invention to provide a burner with an increased range in output power. It is a second object of the present invention to provide a burner with an increased lifetime. It is a third object of the present invention to provide a burner with a reduced production cost. It is a fourth object of the present invention to provide a burner with an improved flame distribution.
A gas burner according the present invention comprises a metal burner membrane. Geometrically this burner membrane comprises a base section and a closing section. The base section has a smallest radius of curvature R_{base}. What is meant with "smallest radius of curvature" will be

explained further on. The base section is connected uninterruptedly to the closing section through a transition region: the transition region burner membrane comprises the same elements as the base and closing section. The transition region has a smallest radius of curvature $r_{transition}$ being larger than zero and being smaller or equal to R_{base}.: $0 < r_{transition} \leq R_{base}$ .The case in which the base section is a plane, hence R_{base} is infinitely large, is not excluded. More preferred is: $0.02 \times R_{base} \leq r_{transition} \leq 0.7 \times R_{base}$. Even more preferred is: $0.02 \times R_{base} \leq r_{transition} \leq 0.35 \times R_{base}$ There is no limitation on the smallest radius of curvature of the closing section.

The notion of "smallest radius of curvature of a section" will now be explained:
Geometrically, at each point of the burner membrane, many radii of curvature can be defined: each of them is associated with a particular cut according a plane containing the normal line at the point under consideration. The intersection of this plane with the burner membrane results in a trajectory. The radius of curvature is the radius of the circle in the intersecting plane, which osculates to second order the trajectory at the point under consideration. Out of all these possible planes, containing the normal line through the point under consideration, with associated trajectories and radii of curvature, the smallest radius is selected. As each point of a section has a smallest radius, the smallest of all smallest radii of the section can be defined to be the smallest radius of curvature of this section. As the radius of curvature is always a positive number, the smallest radius of curvature that may be found is zero. The same definition applies mutatis mutandis to each of the three parts of the burner membrane: the base section, the transition region and the closing section. For each of them a smallest radius of curvature can thus be found. For example: for a base section having a tubular shape with a rounded polygonal cross section this smallest radius of curvature is equal to the radius of the rounding in the edges. Likewise for a cylinder the smallest radius of curvature is equal to half its diameter.

As this geometrical construction must be reduced to practice, it should be clear that the invention relates to the embodiment of this geometrical construction, which of course is subject to engineering tolerances. Hence, it should be clear that the invention is not delimited to the abstract geometrical shape as such but to the shape of the actual burner membrane. This shape can be easily measured by means of an appropriate computerised 3-D measuring bench that allows for immediate determination of the geometrical features in general and the radii of curvature in particular.

The shape of the burner membrane influences the functioning of the burner in the following way: those regions of the burner membrane that have a smaller radius of curvature yield a lower gas speed outside the membrane compared to the regions with a higher radius of curvature. A lower gas speed leads to a lower flame front. So the speed of the gas outside the membrane, and subsequently the flame front, can be advantageously modulated over the surface by changing the radius of curvature.

This yields, amongst others, the following advantages:

- Due to the area of reduced gas speed, the flame is less prone to blow – off.
- Due to the different gas speeds over the burner membrane, a large variation in gas flow rate can be accommodated with the same burner, thus eliminating the need to have different types of burners on stock.
- The area with a smaller radius of curvature, due to the slower gas flow, lends itself advantageously for the ignition of the gas.

According to the present invention the transition from base section to closing section is realised without interruption. With uninterrupted is meant that the membrane forming the different sections (base, transition and closing) are not connected by any means that would lead to a seam of the membrane with a blocked gas flow at the burner surface as a result. I.e. the three sections: base, transition and closing must be gas

permeable. The fact that the burner membrane is free of interruption ensures a closed flame front throughout the whole burner membrane. The three sections (base, transition and closing) can be realised uninterruptedly in one of the following ways:

- by using a fabric of braided or knitted or woven stainless steel fibres. Such fabric can be woven or braided or knitted in such a way that it fulfils the geometrical requirements of the invention;
- by deep drawing or stamping a plate into a shape which fulfils the geometrical requirements of the invention. Small holes must be drilled into the plate in the three sections (base, transition and closing) in order to achieve the desired gas flow;
- by deep drawing or stamping of an already foraminated plate thus eliminating the need for drilling holes into the plate afterwards;
- by deep drawing or stamping a wire mesh where the wires have a suitable thickness and formability

Combinations of the above methods are possible, e.g.

- a fabric of braided or knitted or woven stainless steel fibres which is stretched over a deep drawn or stamped plate in which holes are drilled;
- a fabric of braided or knitted or woven stainless steel fibres which is stretched over a deep drawn or stamped foraminated plate;
- a fabric of braided or knitted or woven stainless steel fibres that is supported by a deep drawn or stamped wire mesh. The wire mesh can also be integrated into the stainless steel fibre fabric i.e. it can be interbraided or interknitted or interwoven with the stainless steel fibres.

It is clear that the above enumeration is non-exhaustive and even different possibilities according the claims of this invention are possible.

By realising the burner membrane in this way, one or more of the following advantages, amongst others, can be achieved:

- a reduction in production cost is obtained by elimination of the welding seams and the assembly of the different parts of the prior art

burners, by the use of a deep drawn or stamped plate or foraminated plate;

- an improved lifetime of the gas burner is obtained due to the elimination of the welding seams;
- the use of stainless steel fibres on top of the foraminated plate isolates the flame from the plate and results in a lower thermal stress on the foraminated plate and hence an improved lifetime;
- the use of stainless steel fibre results in a further random scattering of the gas flow upon exit of the feed through holes which leads to an improved flame distribution.

The uninterrupted burner membrane ensures a flame front in every section of the burner and in particular in the transition region. This improves greatly the stability of the flame.

Brief description of the drawings.

The invention will now be described into more detail with reference to the accompanying drawings wherein

- FIGURE 1 illustrates the basic geometrical principles of the invention in perspective view.
- FIGURE 2 illustrates a preferred embodiment of the invention in perspective view
- FIGURE 3(a) shows a cut of the preferred embodiment along the line A, A' of Fig. 2 along with the geometrical elements.
- FIGURE 3(b) shows a cut of the preferred embodiment along the line A, A' of Fig. 2 along with the physical features.
- FIGURE 4 (a) shows a second preferred embodiment based on a rectangular cross section of the base section.
- FIGURES 4(b) and 4(c) show the section through planes AA' and BB' of Fig. 4(a) respectively.
- FIGURE 4(d) shows a top view cross section of the burner of Fig. 4(a), through the middle of the base section.
- FIGURE 5(a) shows a third preferred embodiment in side view.
- FIGURE 5(b) shows the third preferred embodiment from above.

- FIGURE 5(c) shows an alternate to the third preferred embodiment in side view.
- FIGURE 6(a) shows a fourth preferred embodiment in side view.
- FIGURE 6(b) shows the fourth preferred embodiment from above.
- FIGURE 6(c) shows an alternate to the fourth preferred embodiment in side view.

Description of the preferred embodiments of the invention.

The basic geometrical features of the invention are illustrated in Figure 1 where a shape 100 of a burner membrane is depicted consisting out of a base section 102, a transition section 104 and a top section 106. Take 'a' as point under consideration. 'a' has its normal N to the surface. The planes P1, P2 and P3, all containing the normal N, cut the surface of the burner along different trajectories T1, T2 and T3 respectively. The osculating circle C touches T1 in 'a'. If will be clear that of all planes containing N, the plane P1 determines the trajectory T1 with the smallest radius of curvature R(a) at 'a'. If now for every point 'x' (not indicated on figure 1) of the transition section this R(x) is determined, the smallest value of all R(x)'s can be chosen. When the procedure is applied to the base section 102 a smallest radius of curvature 'R_{base}' is obtained. Similarly, a smallest radius of curvature '$r_{transition}$' can be found for the transition region. It is essential to the invention that the smallest radius of curvature of the transition region is smaller or equal than the smallest radius of curvature of the base section.

Figure 2 depicts a first preferred embodiment 200 in perspective view. The base section 201 is frustoconical in shape and reaches its minimum radius of curvature on the circle 204. The transition region 202 is a surface section of a torus and the closing section 203 is a flat disc.

Figure 3 (a) shows the geometrical elements of the first preferred embodiment of Figure 2 according the line AA'. Only the outer surface of the surface membrane is depicted in order to bring forward the geometrical elements. The frustoconical base section 201 has its

smallest radius of curvature at the smaller diameter side. The half top angle of the cone 326 was about 30° although 0° (a cylindrical base section) turned out to work just as well (embodiment not shown). Higher top angles – the maximum being 90°, a flat plane – are also not excluded. All points on the circle 204 share the same minimum radius of curvature R_{base} 328. The sphere 320 with radius R_{base} defines the largest 'smallest radius of curvature' the transition region may have according the invention. The transition region is part of the surface of a torus formed by a circle 324 that is rotated around the symmetry axis 340. Hence, the radius of circle 324 determines the radius of the transition region '$r_{transition}$' 330. Part of a torus surface between the plane of circle 204 and a plane parallel to the latter is taken as the transition region. Let it be clear that the torus can also be constructed by rotating an ellipse or an oval or any other rounded figure around the axis of symmetry 340. Also the case, in which the torus is degenerate i.e. when there is no hole in the middle, is not excluded. This is e.g. the case in Figure 3a. The closing section 203 is a flat disc in this embodiment. In another preferred embodiment of this invention (no figure provided) the closing section is a small inverted sphere cap thus entailing a depression at the centre of the burner membrane.

It will be clear from this embodiment that the crossover from base section to transition region need not be smooth (with 'smooth' is meant continuous first order derivatives) but must be uninterrupted (zero order continuity).

Figure 3b depicts the physical features of the first preferred embodiment along the cut according plane AA' indicated in Figure 2. 201' indicates the stamped foraminated metal plate made out of a single piece of metal plate. The foraminated metal plate is provided with a number of holes. As the hole size is relatively large (1 mm for this embodiment), the change in hole size at the transition region due to the deformation of the plate is not relevant to the flow speed of the gas. In order to spread the gas a piece of knitted metal fibre fabric 305 is tensioned over the base

section, the transition section and the closing section. In this preferred embodiment, the fabric was attached to the foraminated plate by means of spot welding although other means of fastening are equally well possible for example – without being exhaustive - by sewing or by stapling. In another preferred embodiment (no figure provided), the fabric was kept on the foraminated plate by means of a clamping ring that was spot welded to the plate.

Knitted metal fibre fabric allows for a high elongation thus leading to a continuous transition from the base section to the closing section. The arrows 307, 308 and 309 indicate the velocity of the gas as it flows out of the membrane. The lower gas velocity in the transition region 202 is represented with a shorter vector 308, while the gas velocity at the base section 201 and the closing section 203 is higher which is represented by a longer vector 309 resp. 307. Also the lower flame front 310 – where the gas ignites – and the outer flame front 313 – where the top of the flame is – is indicated for each of the sections.

With this preferred embodiment, it was possible to achieve a maximum heating power of 40 kW/dm². A minimum heating power of 1 kW/dm² was necessary in order to get a stable flame. This yields an overall dynamic range of 1: 40.

In Figure 4 a preferred embodiment is illustrated that is more suited for replacement of a rectangular type burner. Here the cross-section of the base section is essentially rectangular of which the edges are rounded. Figure 4b is a cross-section along plane AA' of Figure 4a: the base section 401 smoothly goes over into the transition region 402 which approximates the upper half of an ellipse with a minor half axis indicated by 406 and a major half axis indicated by 405. 407 indicates the osculating circle associated with the smallest radius of curvature of the transition region. Figure 4c shows a cut along the line BB'. Figure 4c shows an essentially identical shape as the AA' cut, but here the half ellipse has been cut in two, and the two quarter pieces have been displaced the appropriate distance. Figure 4d shows the closing view of

a horizontal cut. The rounded corners have essentially merged into a semicircle with a radius equal to the half major axis of the ellipse as described in Figure 4b.
Note that in this embodiment, the closing section has vanished into a single line 408.

In a third preferred embodiment illustrated in Figure 5a and 5b the foraminated plate 201'of Figure 3b was replaced by a stainless steel wire mesh 520. The diameter of the wires was 0.48mm, with a square 24/24 mesh size (24 wires per inch) in a 2/2 twilled weave. The minimum radius of curvature 506 in the transition region 502 was equal to 4 mm although a radius from 2 to 8 mm works equally well. The value of the minimum radius of curvature 508 of the base section 501 was 25 mm and is preferably in the range of 30 to 45 mm. The closing section is a flat disc 504. A knitted metal fibre fabric 512 was spot welded to the wire mesh.

An alternative to the third embodiment is depicted in Figure 5(c). Like parts of the burner membrane according the third embodiment are identified with primed numbers. The transition region 502' is in the form of a circular ridge. The top of the ridge has a radius of curvature 506', which turns out to be the smallest radius of curvature of the transition region.

In a fourth preferred embodiment illustrated in Figure 6a and 6b, again a stainless steel wire mesh 610 was used. The base section 601 has a very large minimum radius of curvature, the transition region 602 has a minimum radius of curvature indicated by 606, while the closing section vanishes to a single line 604. The minimum radius of curvature of the transition region 606 is 9 mm although values from 3 mm upward are also possible.

An alternative to the fourth embodiment is depicted in Figure 6(c). Again like parts of the burner membrane according the fourth embodiment are

identified with primed numbers. The transition region 602' is in the form of a ridge extending substantially the length of the longitudinal burner membrane. The top of the ridge has a radius of curvature 606', which turns out to be the smallest radius of curvature of the transition region. Again the closing section vanishes into a line 604'.